

Factorisation in diffractive photoproduction at HERA

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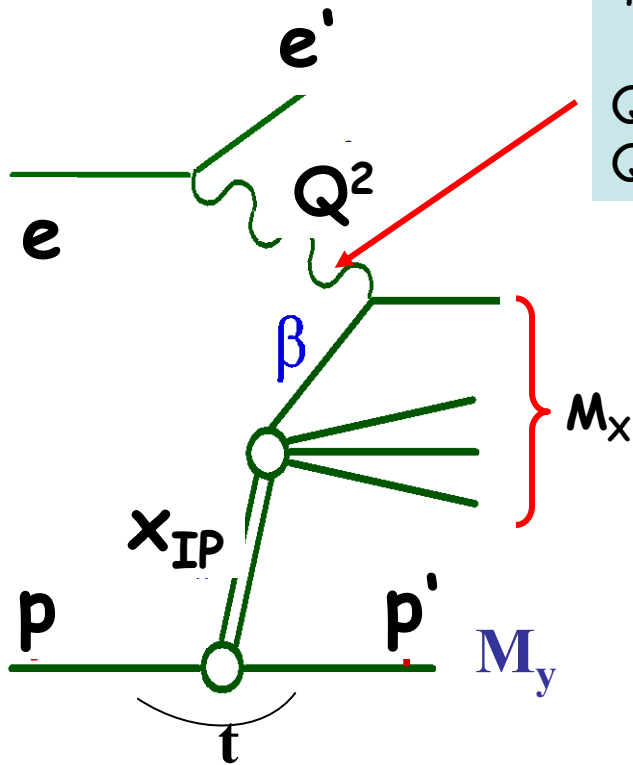
Low x workshop, Santiago de Compostela, 2011

Diffraction and diffraction kinematics

Two kinematic regions of diffractive events:

$Q^2 \sim 0 \rightarrow$ photoproduction

$Q^2 \gg 0 \rightarrow$ deep inelastic scattering (DIS)



$M_y = m_p$ proton stays intact, needs detector setup to detect protons

$M_y > m_p$ proton dissociates, \longrightarrow contribution should be understood

HERA: $\sim 10\%$ of low- x DIS events diffractive

W

$$x_{\text{IP}} = \frac{q \cdot (p - p')}{q \cdot p} \approx \frac{Q^2 + M_x^2}{Q^2 + W^2} \longrightarrow$$

momentum fraction of color singlet exchange

$$\beta = \frac{x}{x_{\text{IP}}} \approx \frac{Q^2}{Q^2 + M_x^2} \longrightarrow$$

fraction of exchange momentum, coupling to γ

$$t = (p - p')^2 \longrightarrow \text{4-momentum transfer squared}$$

Two types of factorisation

QCD factorisation holds for inclusive and non-inclusive processes if:

- photon is point-like (Q^2 is high enough)
- higher twist corrections are negligible (M_x is high enough)

QCD factorisation theoretically proven for DIS (Collins 1998)

$$\sigma^D(\gamma^* p \rightarrow Xp) = \sum_{\text{parton } i} f_i^D(x, Q^2, x_{IP}, t) \cdot \sigma^{\gamma^* i}(x, Q^2)$$

$f_i^D \rightarrow$ DPDFs - obey DGLAP, universal for diff. ep DIS (inclusive, dijet, charm)

$\sigma^{\gamma^* i} \rightarrow$ hard scattering QCD matrix element, perturbatively calculated, process dependent

It allows the extraction of DPDFs from the (DIS) data

H1 and ZEUS -QCD fits assuming **Regge factorisation** for DPDF

$$f_i^D(x, Q^2, x_{IP}, t) = f_{IP/p}(x_{IP}, t) \cdot f_i^{IP}(\beta = x/x_{IP}, Q^2)$$

$$f_{IP/p}(x_{IP}, t) = \frac{e^{Bt}}{x_{IP}^{2\alpha(t)-1}}$$

pomeron flux factor

pomeron PDF

Tests of QCD factorisation

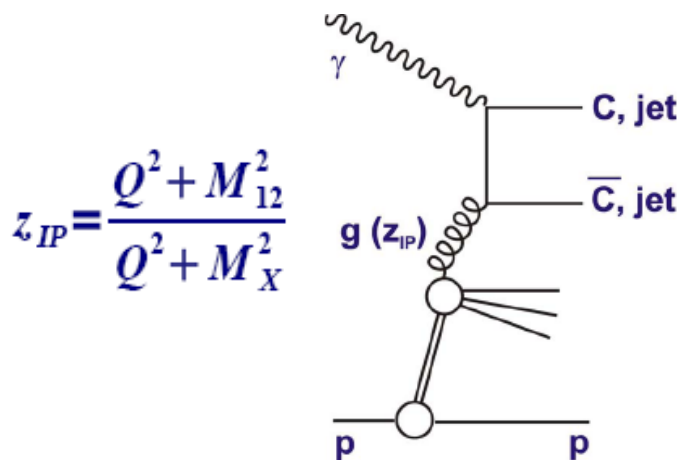
What kind of final states?

- processes with a hard scale
- sensitive to gluons (gluons contribute by up to 80% to the DPDFs).

Dijets and D^* in DIS, D^* in photoproduction - factorisation holds (tested by H1 and ZEUS).

What about dijets in photoproduction?
Similarity with hadron-hadron interactions..

Photoproduction, γp , $Q^2 \rightarrow 0$



direct

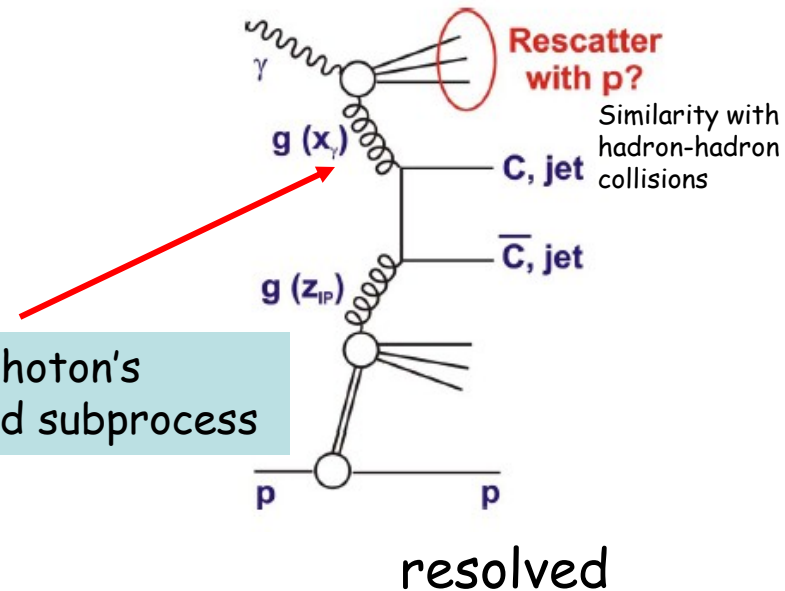
direct photoproduction

photon directly involved in hard scattering

$x_\gamma = 1$ (at parton level)

In LO!

x_γ - fraction of photon's momentum in hard subprocess



hadron-like component

photon fluctuates into hadronic system, which takes part in hadronic scattering

$x_\gamma < 0.2$ (at parton level)

point-like component of resolved photon

dominates in the region of $0.2 < x_\gamma < 1$

Factorisation in hadron-hadron collisions

Exporting DPDFs from HERA to Tevatron does not work

$$S^2 = \frac{\sigma(\text{data})}{\sigma(\text{theory})}$$



suppression factor

Factorisation broken by β -dependent factor ~ 10 , $S^2 \sim 0.1$.

Dijets in diffractive photoproduction

In 2010 new theoretical prediction by KKMR:

(European Journal of Physics 66,373 (2010))

Suppression 0.34 present only for hadronic part of photon PDF ($x_\gamma < 0.2$),
for dominant point-like component 

suppression: quarks GRV **0.71(0.75)** $E_{T^{\text{jet}1}} > 5$ (7.5) GeV

gluons GRV **0.53(0.58)** $E_{T^{\text{jet}1}} > 5$ (7.5) GeV

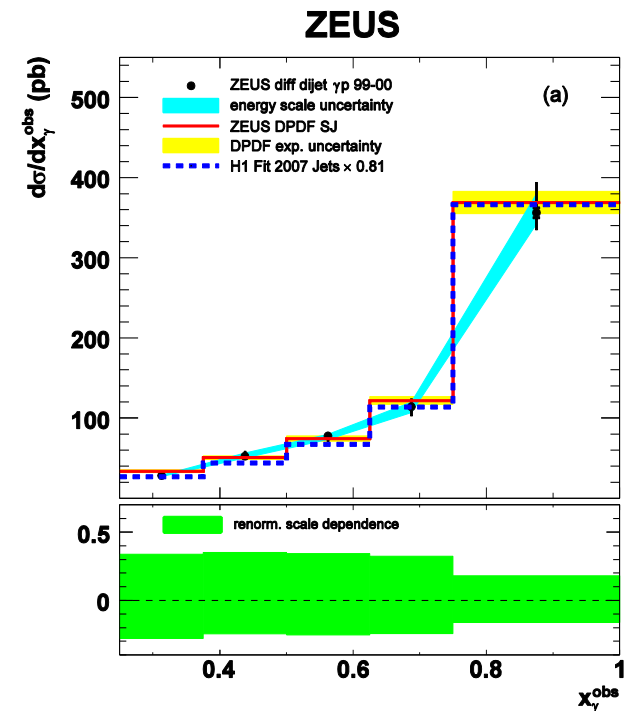
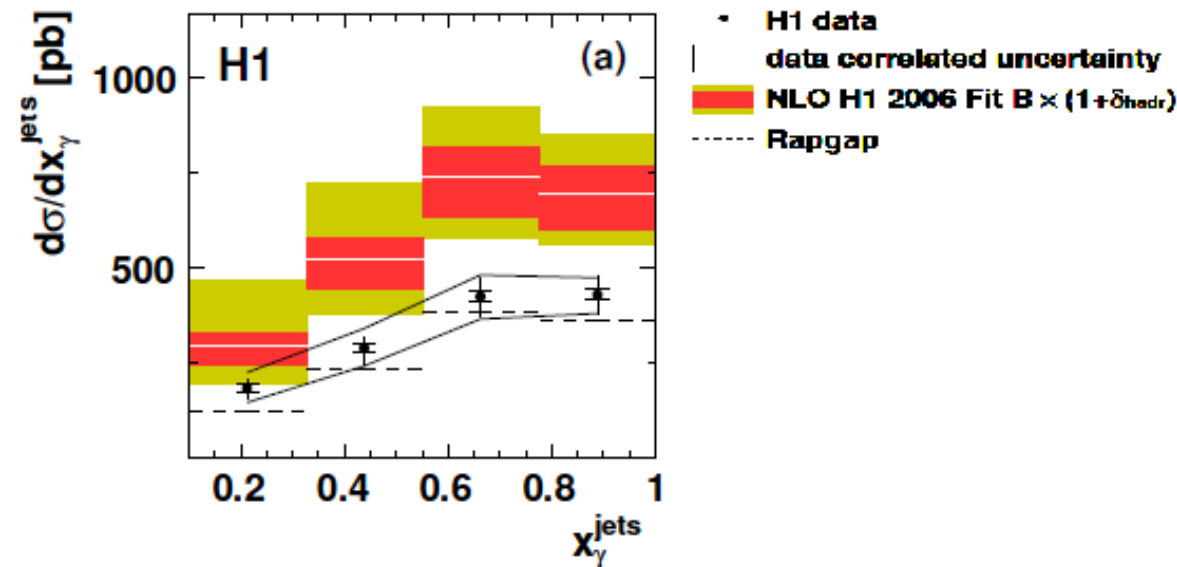
According to theoretical predictions still some
suppression around 0.5-0.8 should exist!

Dijets in photoproduction

Factorisation breaking observed by H1, two analyses,
 EPJC C51 (2007), 549, - suppression ~ 0.5
 EPJ C68 (2010), 381 - suppression ~ 0.6

not observed by ZEUS, Nucl.Phys. B381 (2010), 1 - no suppression

Do we understand this difference?

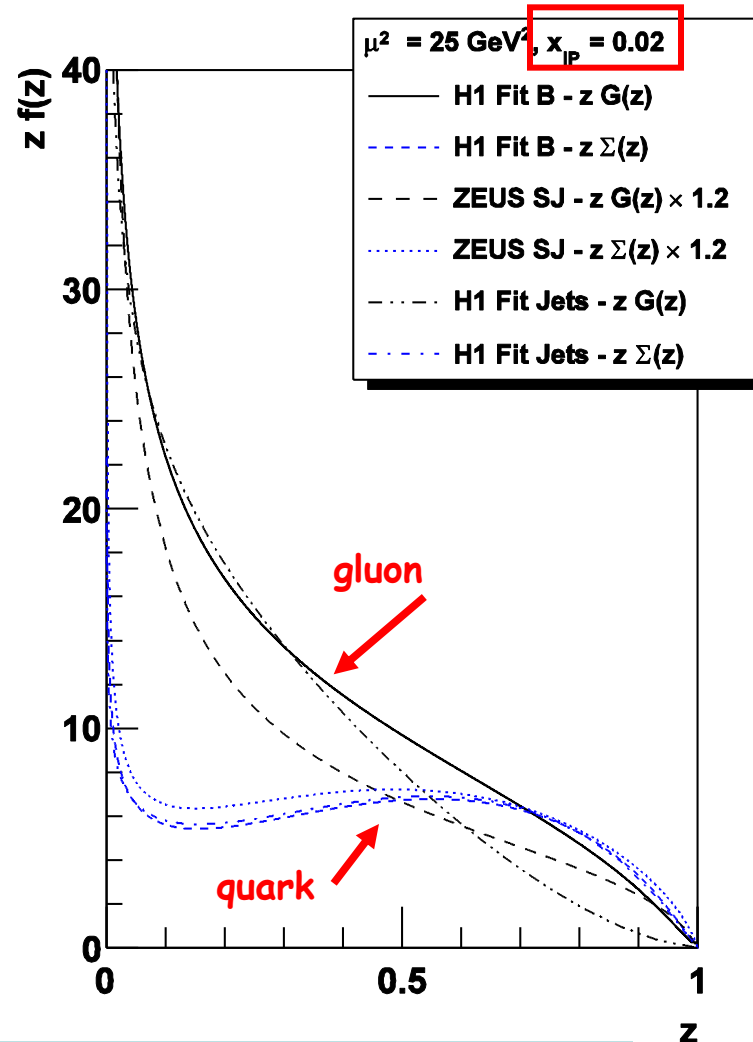
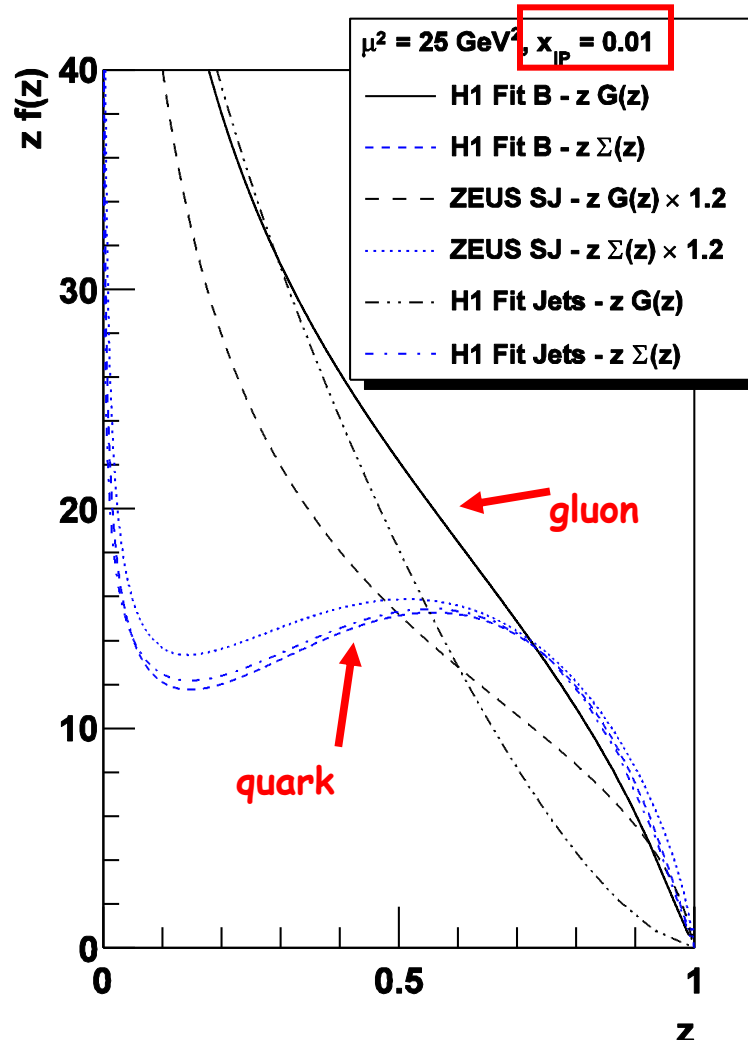


Possible explanation....?

- the **different phase space of both analyses** - larger E_+ of jets in ZEUS analysis etc. (the influence of larger E_+ cut was however not fully confirmed - see EPJ C68 (2010),381)
- in H1 and ZEUS **different hadronisation corrections** (estimated by MC RAPGAP and applied to NLO QCD calculations)
- old **photon structure GRV** - used however by both H1 and ZEUS

Here an attempt to crosscheck critical points....

DPDFs used



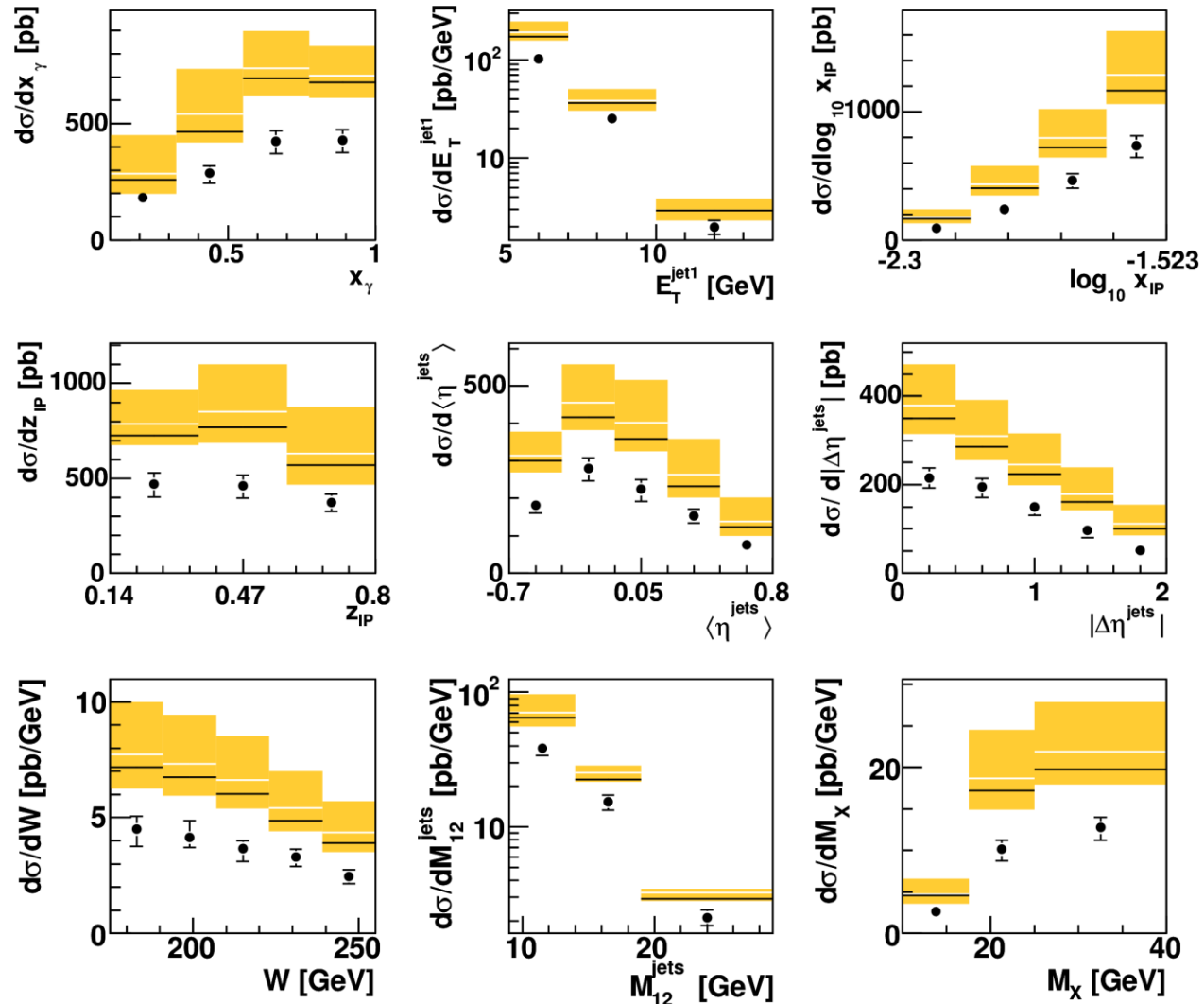
H1 fit B, H1 fit Jets, ZEUS fit SJ

H1 diff. cross sections and NLO

• H1 Data

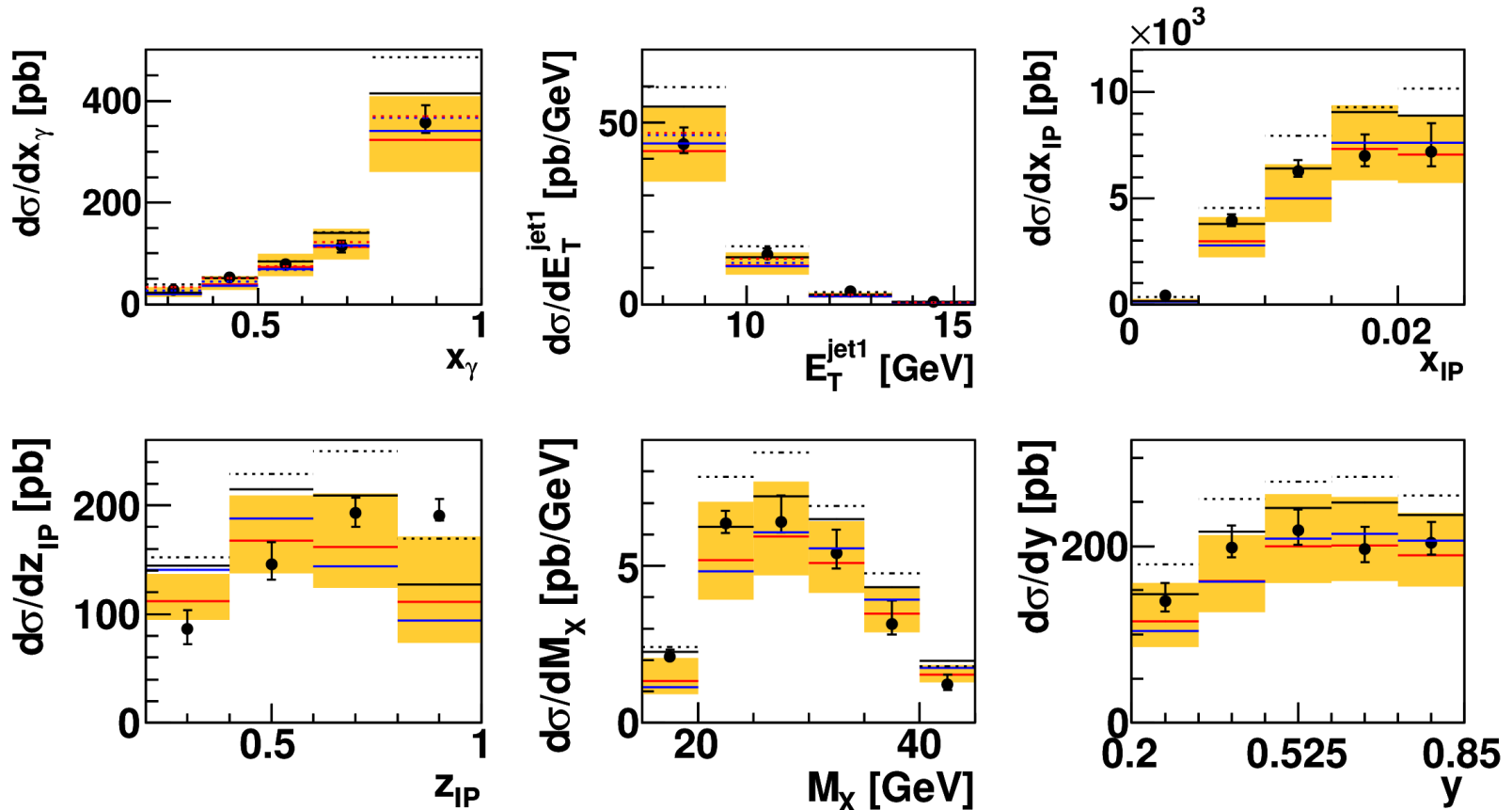
■ H1 Fit B, GRV

— H1 Fit B, AFG



ZEUS diff. cross sections and NLO

- Our calculations (ZEUS fit SJ), suppression ~ 1.1
- ZEUS published (ZEUS fit SJ), suppression ~ 1 .



Extrapolation

H1

Inclusive

$$Q^2 < 0.01 \text{ GeV}^2$$

$$0.3 < y < 0.65$$

$$E_T^{\text{jet1}(2)} < 5(4) \text{ GeV}$$

$$-1 < \eta^{\text{jet1}(2)} < 2$$

Diffractive

$$x_{IP} < 0.03$$

$$|t| < 1 \text{ GeV}^2$$

$$M_Y < 1.6 \text{ GeV}$$

$$z_{IP} < 0.8$$

expansion $Q^2, y, \eta^{\text{jets}}, z_{IP}$

contraction $E_T^{\text{jets}}, x_{IP}, \eta^{\text{jets}}, M_Y$

expansion $\eta^{\text{jets}}, z_{IP}$

contraction $\eta^{\text{jets}}, E_T^{\text{jets}}, x_{IP}$

ZEUS

Inclusive

$$Q^2 < 1 \text{ GeV}^2$$

$$0.2 < y < 0.85$$

$$E_T^{\text{jet1}(2)} < 7.5(6.5) \text{ GeV}$$

$$-1.5 < \eta^{\text{jet1}(2)} < 1.5$$

Diffractive

$$x_{IP} < 0.025$$

$$|t| < 1 \text{ GeV}^2$$

$$M_Y = M_P$$

H1 – high Pt

Preliminary

Inclusive

$$Q^2 < 0.01 \text{ GeV}^2$$

$$0.3 < y < 0.65$$

$$E_T^{\text{jet1}(2)} < 7.5(6.5) \text{ GeV}$$

$$-1.5 < \eta^{\text{jet1}(2)} < 1.5$$

Diffractive

$$x_{IP} < 0.025$$

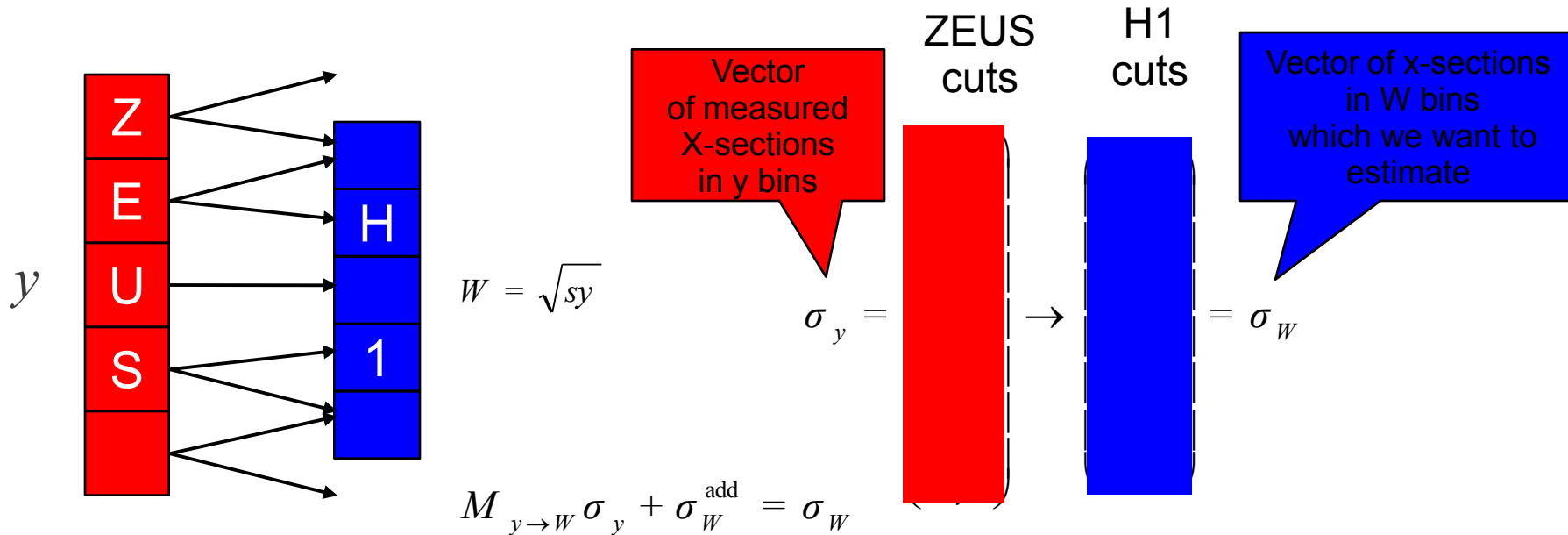
$$|t| < 1 \text{ GeV}^2$$

$$M_Y < 1.6 \text{ GeV}$$

expansion M_Y

contraction Q^2, y

Method of Extrapolation



$$(M_{y \rightarrow W})_{ij} = p_{yj \rightarrow Wi}$$

Transition matrix

$$p_{yj \rightarrow Wi}$$

Probability that event in yj bin will be registered in Wi (from MC fitted to the data)

$$\sum p_{yj \rightarrow Wi} \leq 1$$

Some events missing

$$\sigma_W^{\text{add}}$$

Vector of x-sections of events which don't fulfill H1 cuts but agree with ZEUS (from MC RAPGAP)

Test of method

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$$z_{IP} < 0.8$$

expansion $\eta^{\text{jets}}, z_{IP}$

contraction $\eta^{\text{jets}}, E_T^{\text{jets}}, x_{IP}$

H1 – high Pt

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$$Q^2 < 0.01 \text{GeV}^{-2}$$

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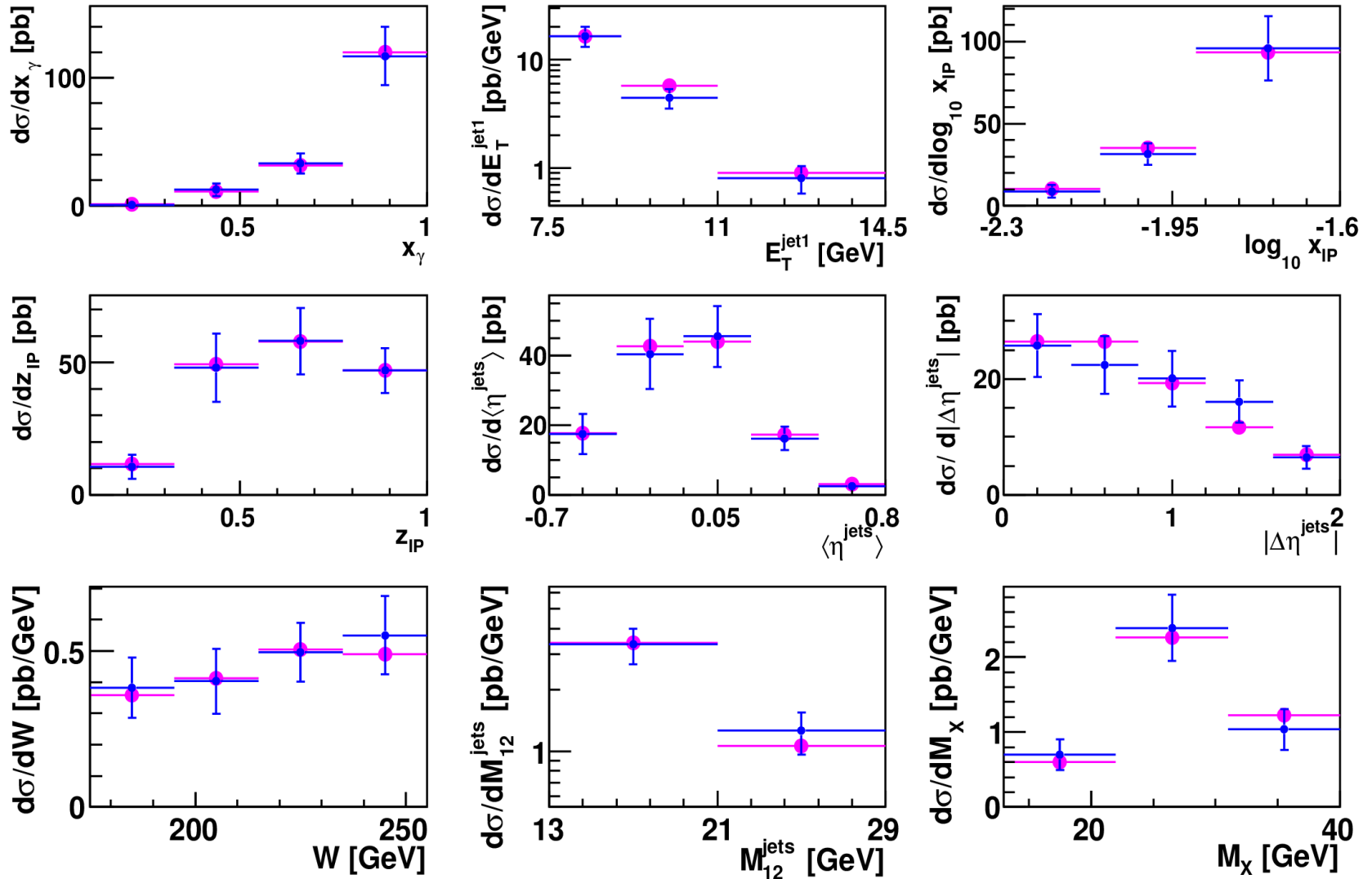
$$|t| < 1 \text{GeV}^{-2}$$

$$M_Y < 1.6 \text{GeV}$$

See: K.Černý, talk in DIS08,
London 2008

Results, $H1 \rightarrow H1$ High P_{T}

- H1 High Pt Data - Preliminary
- H1 Low Pt - Extrapolated



Extrapolation

H1

Inclusive

$$Q^2 < 0.01 \text{ GeV}^2$$

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$$E_T^{\text{jet1}(2)} < 5(4) \text{ GeV}$$

$$-1 < \eta^{\text{jet1}(2)} < 2$$

Diffractive

$$x_{IP} < 0.03$$

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expansion $Q^2, y, \eta^{\text{jets}}, z_{IP}$

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Diffractive

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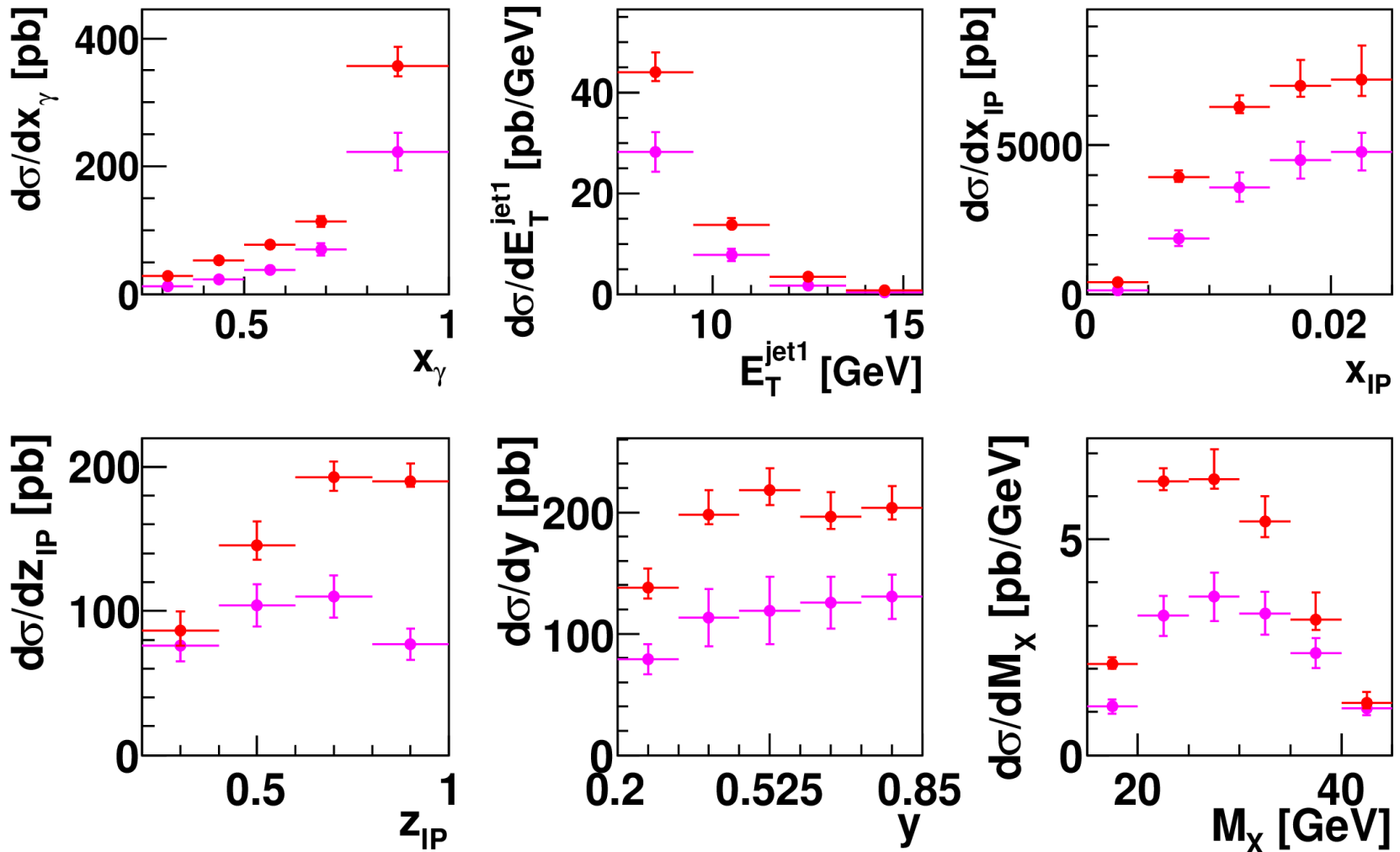
$$M_Y = M_P$$

Results, $H1 \rightarrow ZEUS$

—●— H1 Low Pt - Extrapolated

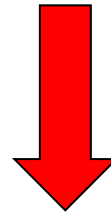
—●— ZEUS Data - Published

Suppression of H1 data & ZEUS data is ~ 0.6



Conclusions

- NLO calculations (with 3 DPDFs) and hadronisation corrections checked for H1 and ZEUS
- Sensitivity to photon structure function checked
- H1 data extrapolated with the help of MC RAPGAP to ZEUS phase space



Data of H1 and ZEUS are different in the identical (ZEUS) phase space....